



MEMS 2003 and Beyond

A DARPA Vision of the Future of MEMS

Albert P. Pisano, Ph. D.

MEMS Program Manager
Microsystems Technology Office
Defense Advanced Research Projects Agency

(703) 696-2278
apisano@darpa.mil
<http://www.darpa.mil/MTO/MEMS/>



What Are MEMS?



- A way of making things
 - Leveraging on existing infrastructure of IC fabrication tools
 - Prototype on the exact mass-production fabrication tools
- Co-location of sense, compute, actuate, control, communicate, power
 - Increase performance and decrease cost
 - Integrate an increased number of fabrication technologies
- Closed-loop, microscale control of electrical, thermal, fluid, magnetic, optical, and mass flux
 - **MEMS is a surface technology**
 - **Control phenomena on the microscale**
 - **Cause large effects both on macroscale and microscale**



What Are MEMS?



- High spatial resolution and high temporal bandwidth
 - Integrated solutions offer greater physical density
 - Miniaturized components offer faster response
- MEMS at both microscale and macroscale
 - Large array of MEMS on a chip
 - Large array of MEMS “islands” on a macro platform
 - Dual-scale interconnect problem (integration required)
- The relevant size metric is the minimum feature size
 - Overall device or system size is irrelevant
 - Minimum feature size determines the required technology
- MEMS as Analog of Transistors
 - Direct and/or control power from macro and other sources



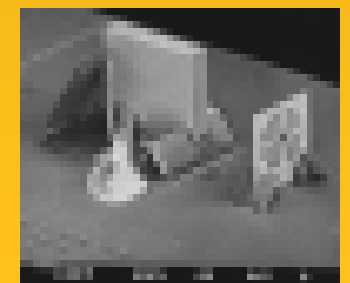
Defense Applications of MEMS



MTO

MEMS

- Inertial navigation units on a chip for munitions guidance and personal navigation
- Electromechanical signal processing for ultra-small, ultra low-power wireless communication
- Distributed unattended sensors for asset tracking, environmental monitoring, security surveillance
- Integrated fluidic systems for miniature analytical instruments, propellant and combustion control
- Weapons safing, arming and fuzing
- Embedded sensors and actuators for condition-based maintenance
- Mass data storage devices for high density, low power
- Integrated micro-optomechanical components for identify-friend-or-foe systems, displays and fiber-optic switches
- Active, conformable surfaces for distributed aerodynamic control of aircraft and adaptive optics





What is the Future of MEMS?



MEMS is an enabling technology that will be part of both macro and micro systems.

- **Wrist Communicator**
- **Robust Jet Engine**
- **Stand-Off Chemical Sensing**
- **Micro Airborne Sensor/Communicator**
- **Micro Thermal-Chemical Power Systems**

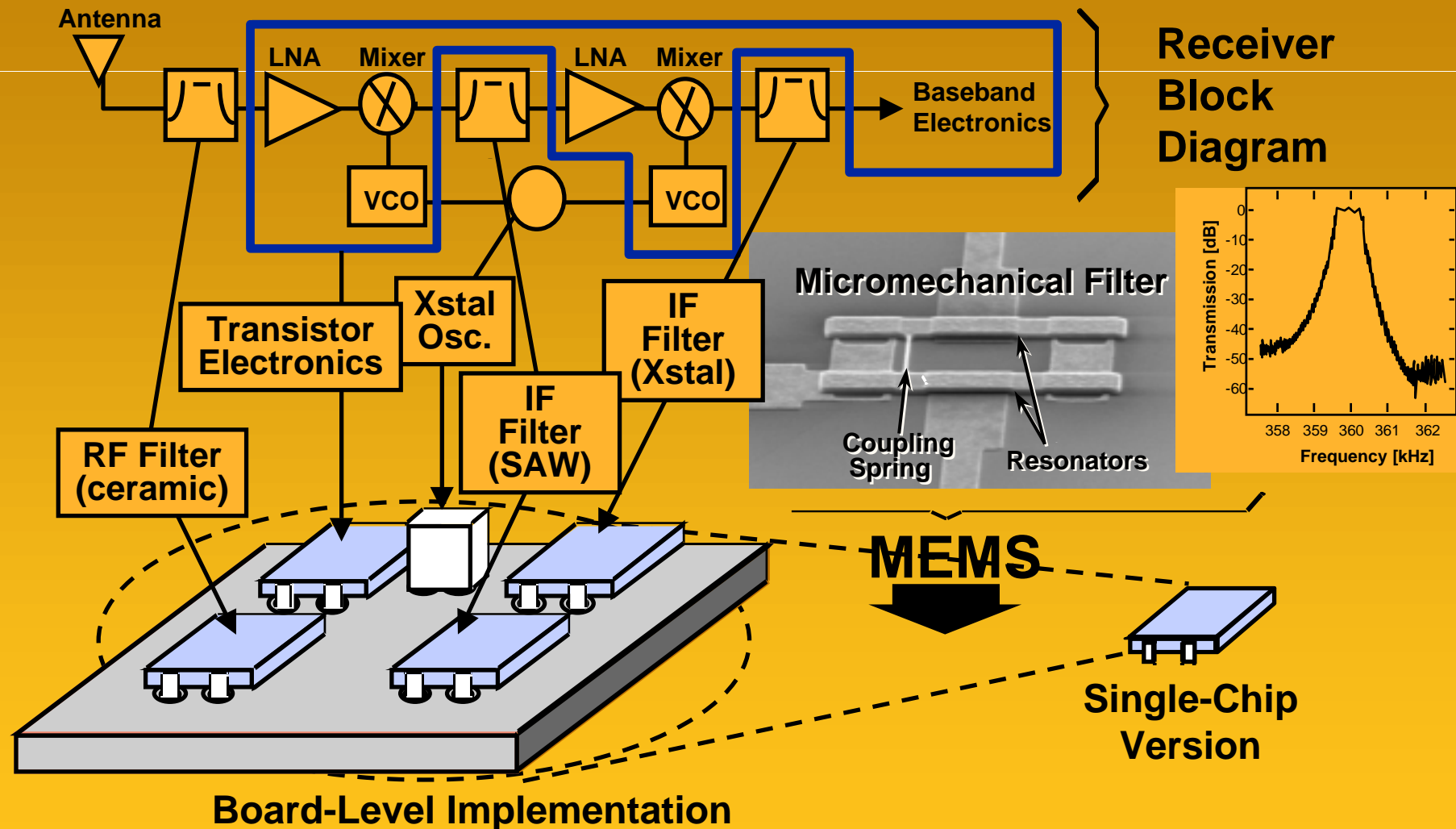


Wrist Communicator



MTO

MEMS



Univ. of Michigan
MEMS for Signal Processing

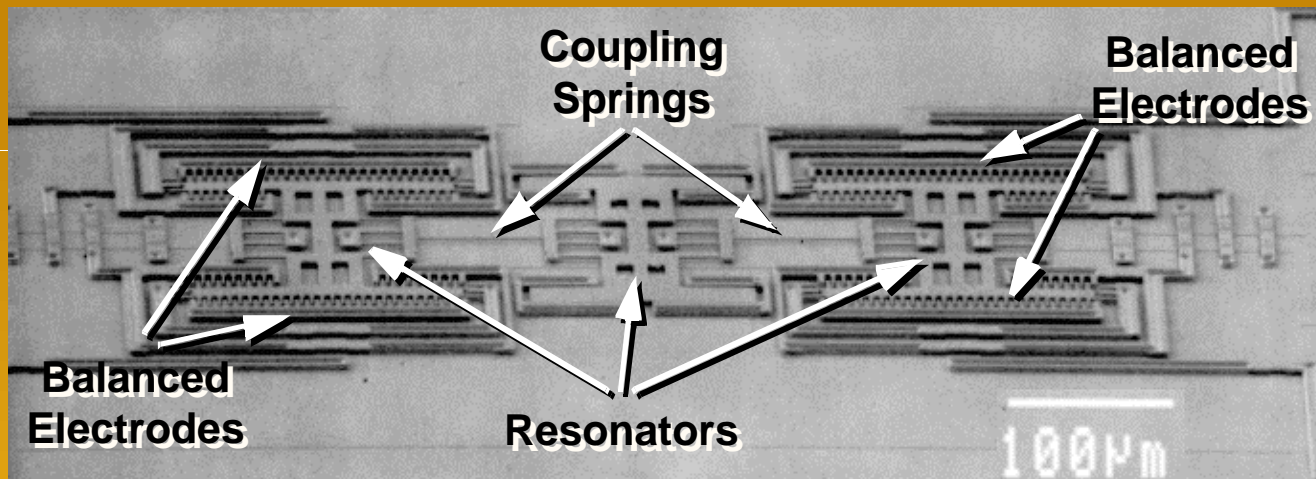


Wrist Communicator

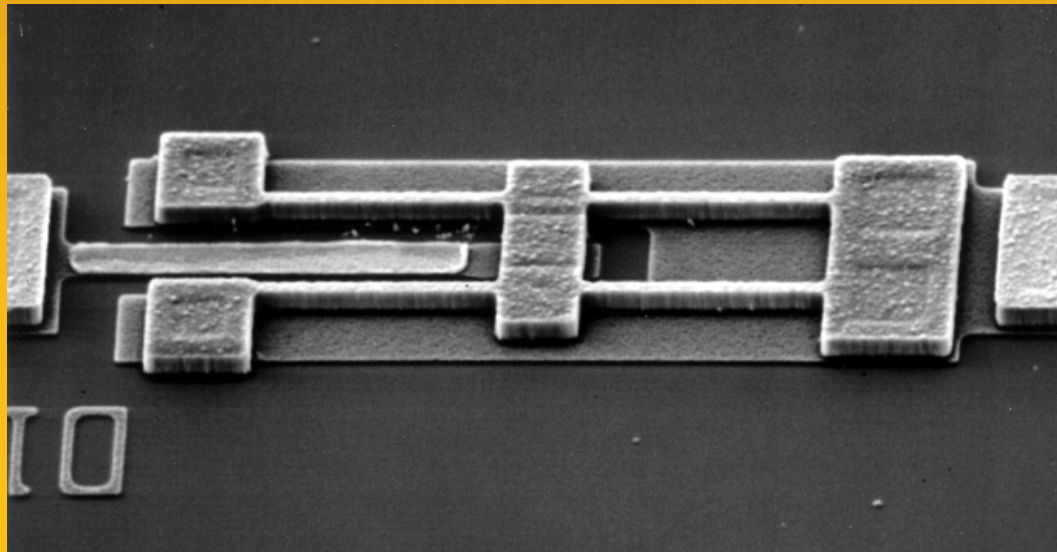


MTO

MEMS



Sixth-Order Bandpass Filter with Audio Center Frequency



Fourth-Order Bandpass Filter with 71 MHz Center Frequency

Univ. of Michigan
MEMS for Signal Processing

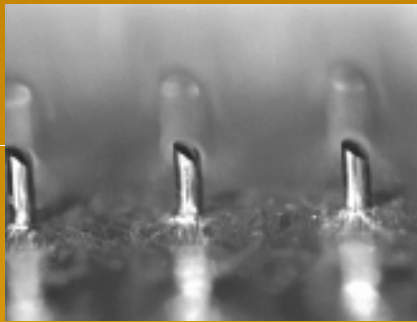


Robust Jet Engine

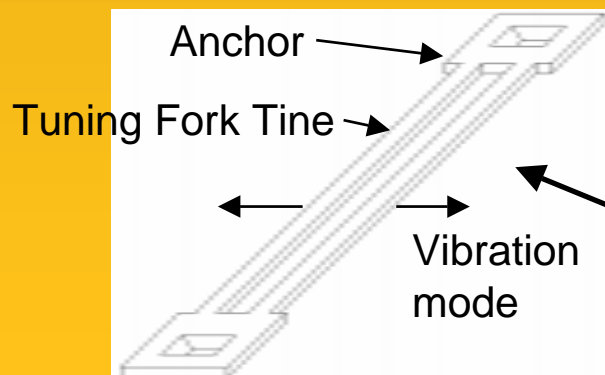
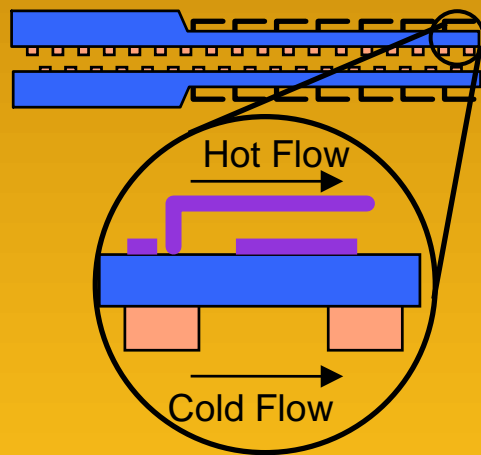


MTO

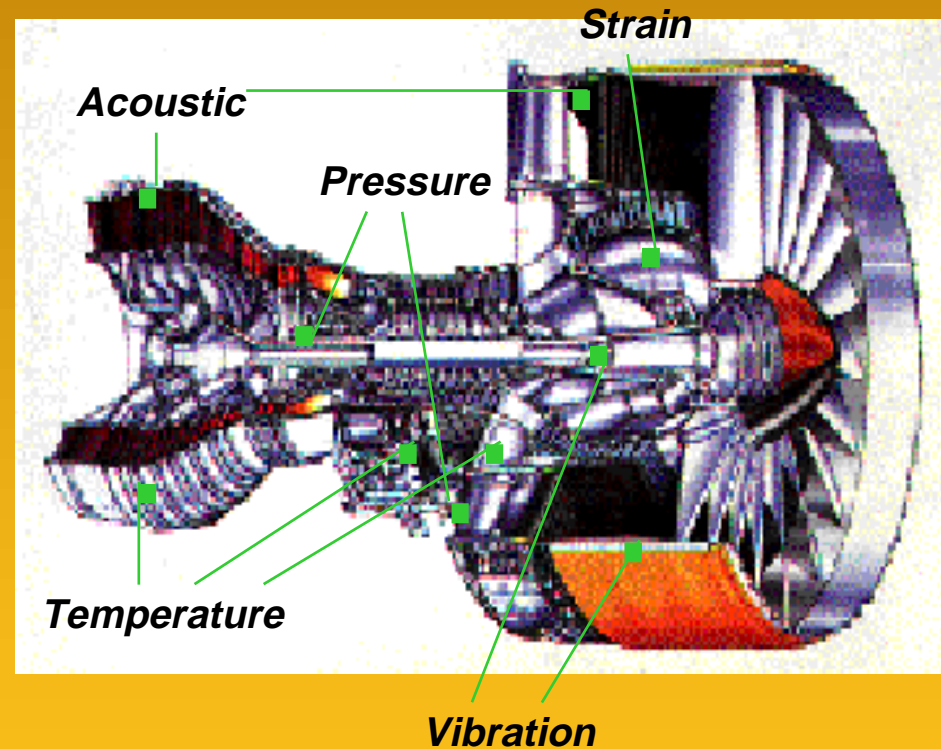
MEMS



Micro heat fins 150 μm diameter, 500 μm tall, spaced on 1.0 mm centers on a 1.7 cm diameter rod. (LSU)



Micro resonant strain gage with over 10,000x sensitivity of metal foil strain gages. Nominal sensitivity 600Hz/ μstrain . (UCB)



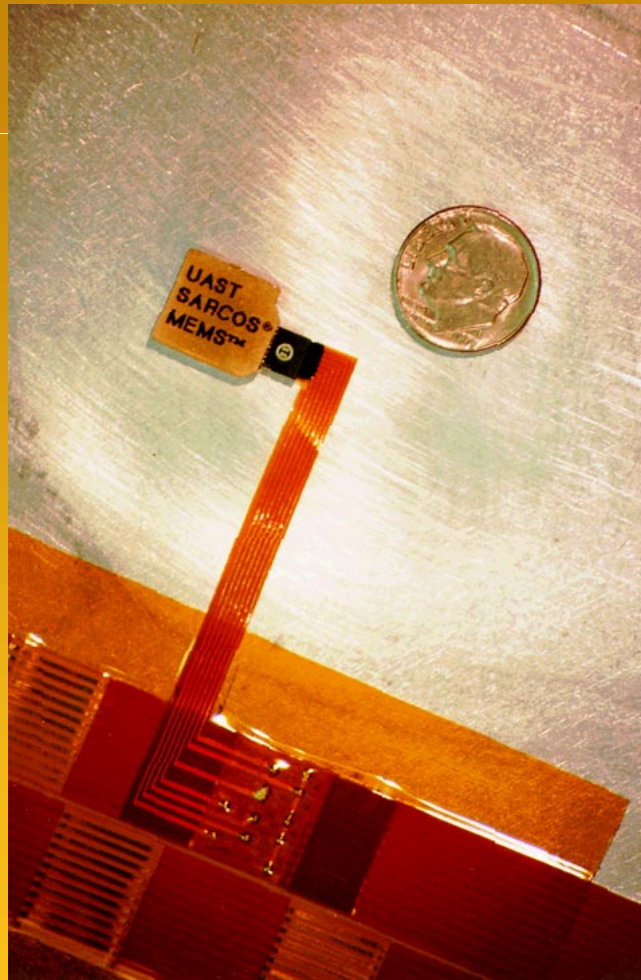


Robust Jet Engine



MTO

MEMS



UAST Demo on 1/2-Scale F/A-18 Tail

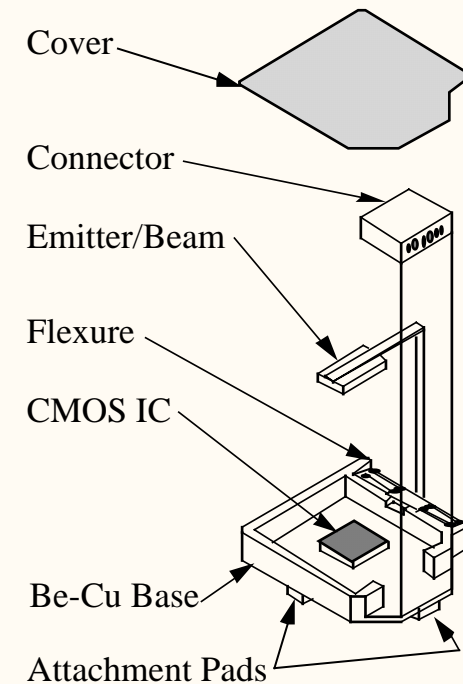
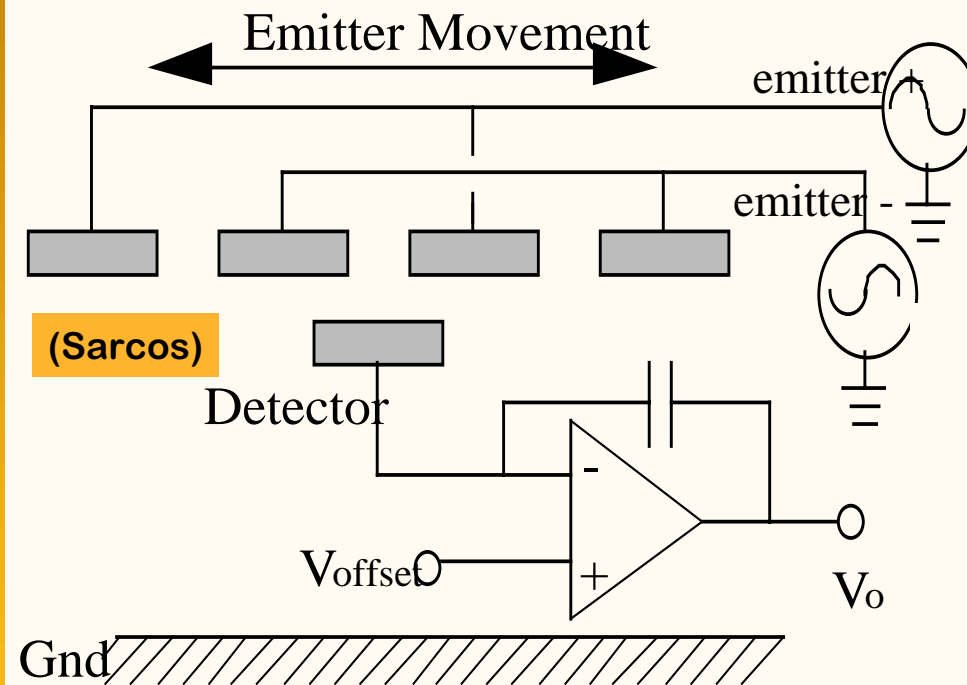


Robust Jet Engine



MTO

MEMS





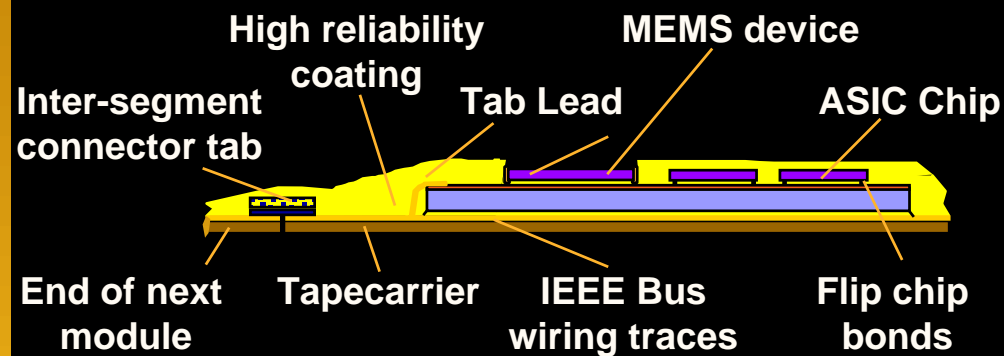
Robust Jet Engine



MTO

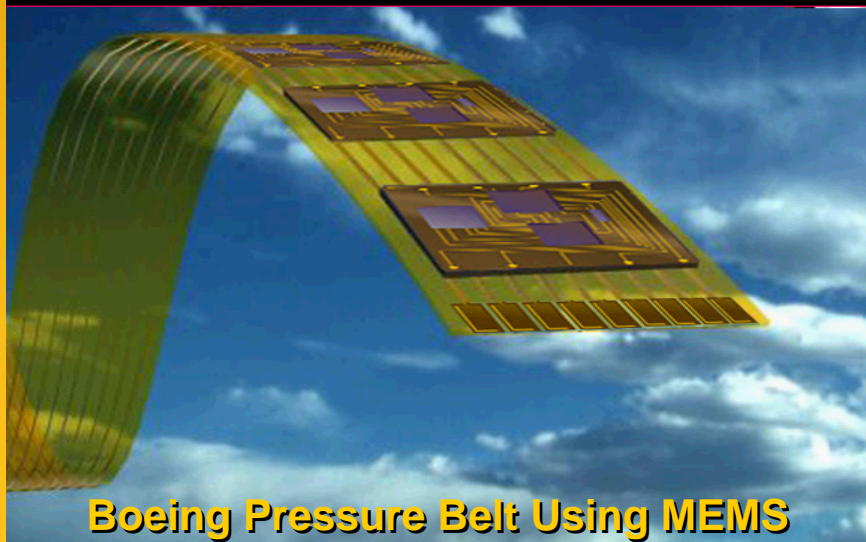
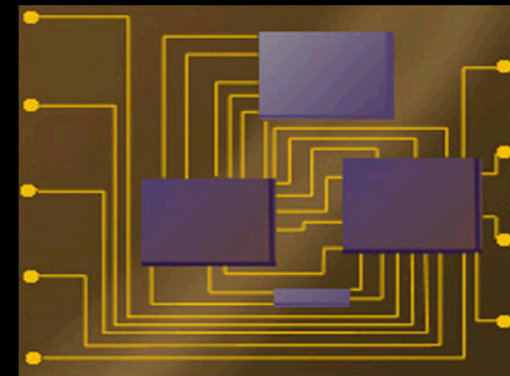
MEMS

Pressure Belt Cross Section

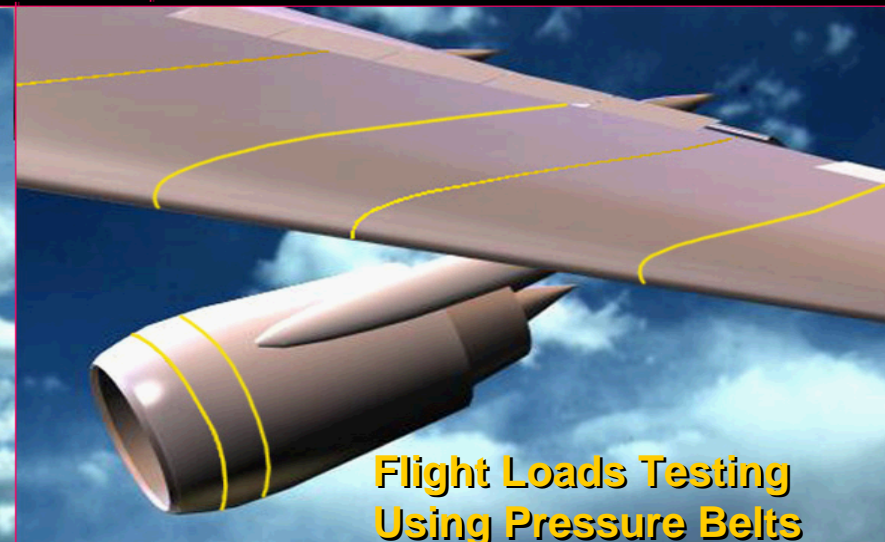


(Vertical scale enlarged for illustration only)

MEMS Sensor Integrated on an MCM with Embedded Passives



Boeing Pressure Belt Using MEMS



Flight Loads Testing Using Pressure Belts



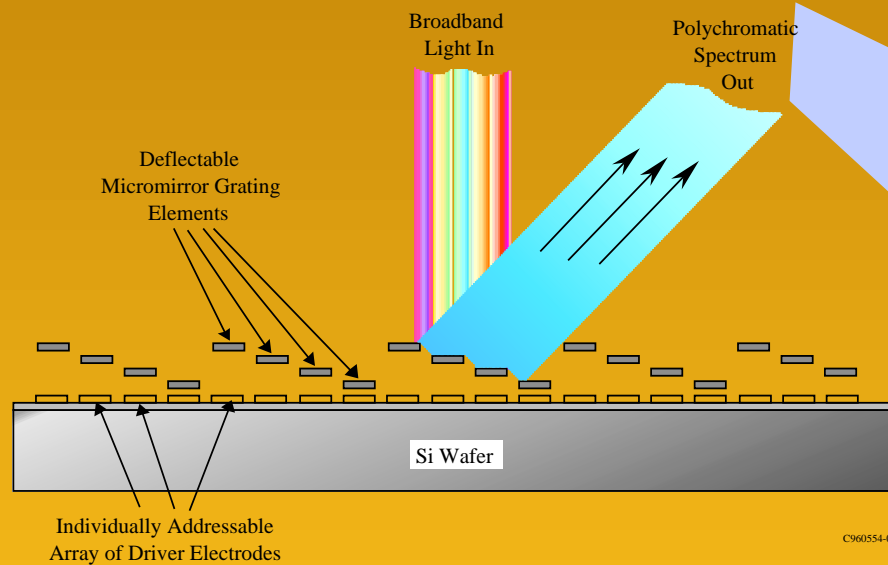
Micro Airborne Sensor/Communicator



MTO

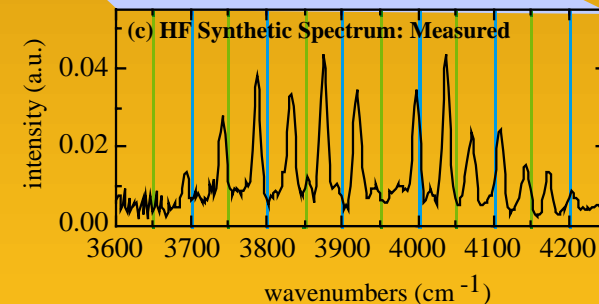
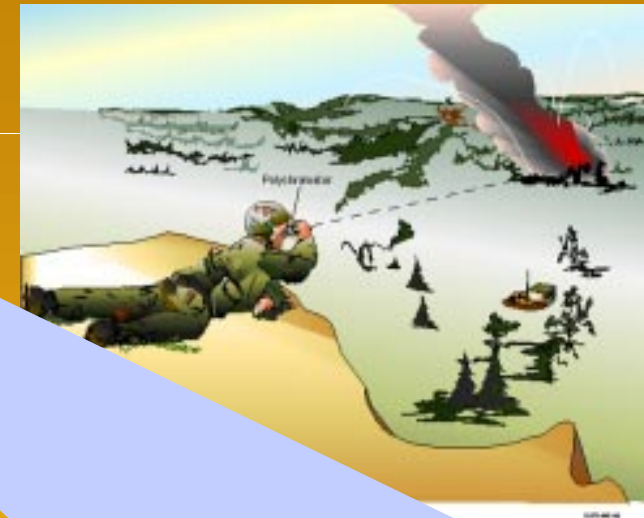
MEMS

MEMS Polychromator



C960554-06

Honeywell Corp.



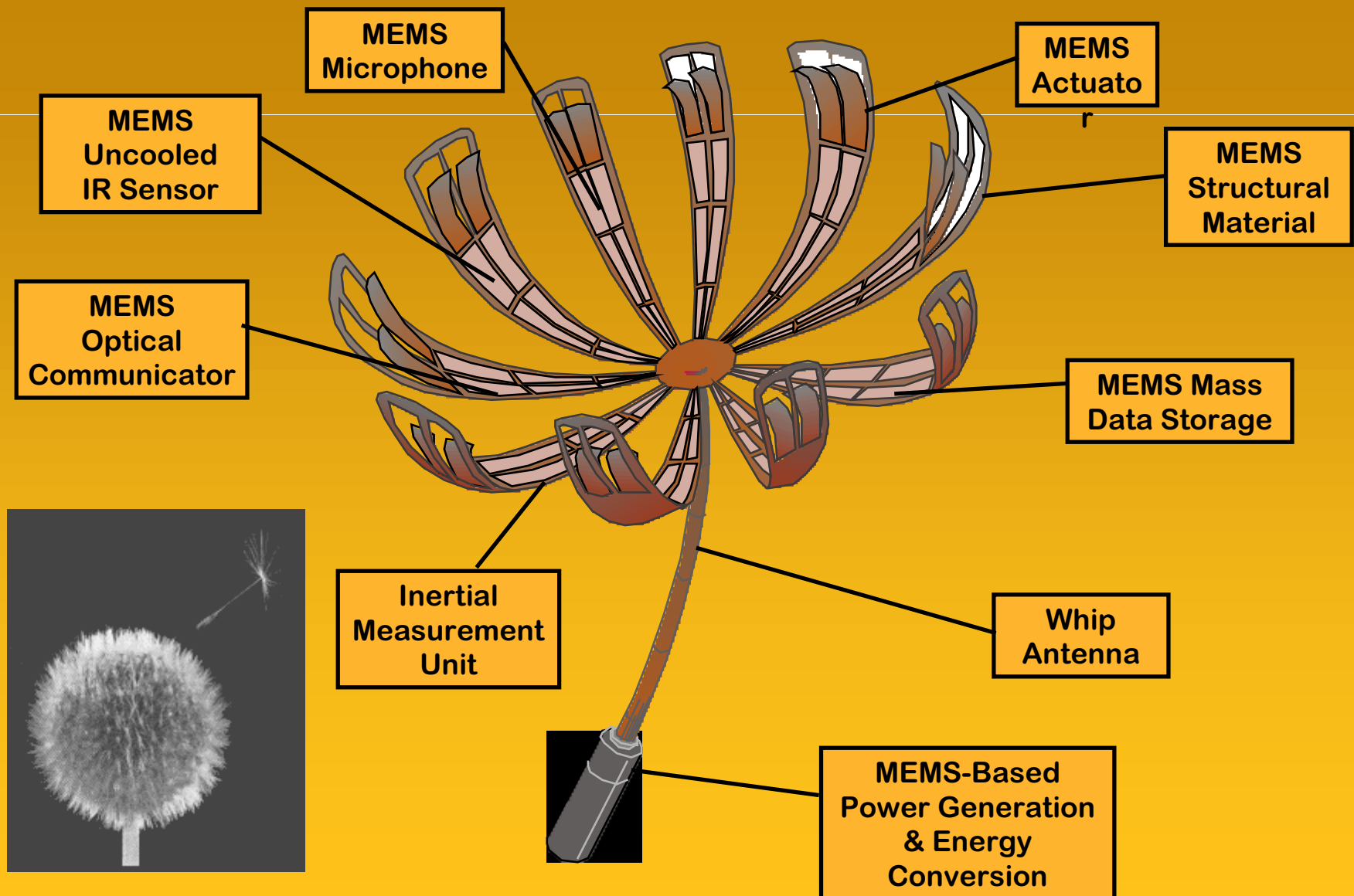
- A new concept for an electronically programmable, dark-field correlation spectrometer based on a MEMS diffraction grating.
- Leads to development of a miniature, electronically programmable remote chemical detection system for field use.



MTO

MEMS

Micro Airborne Sensor/Communicator



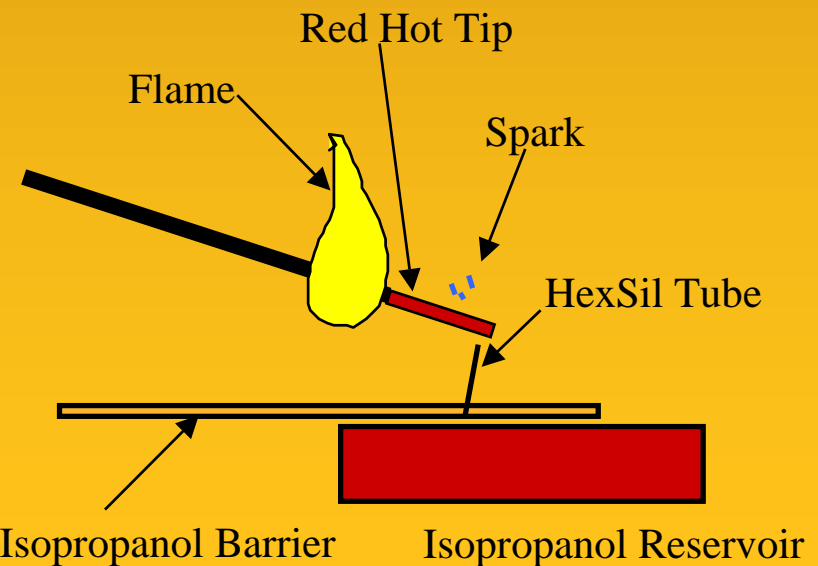
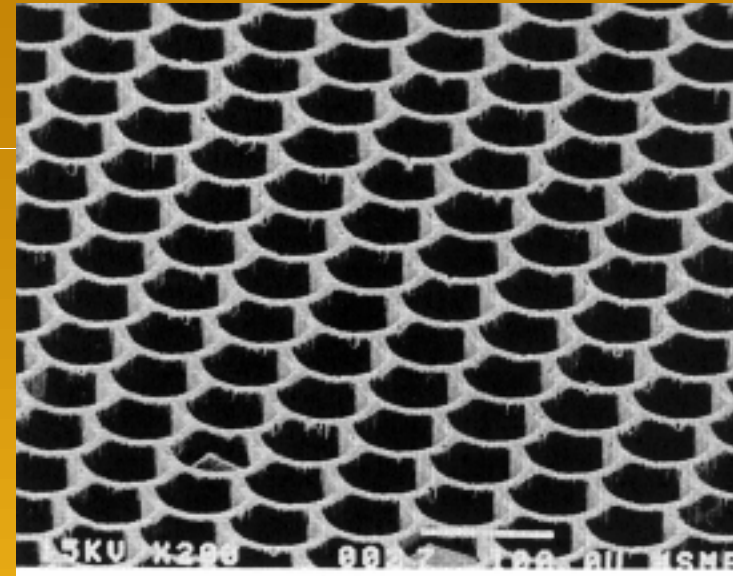
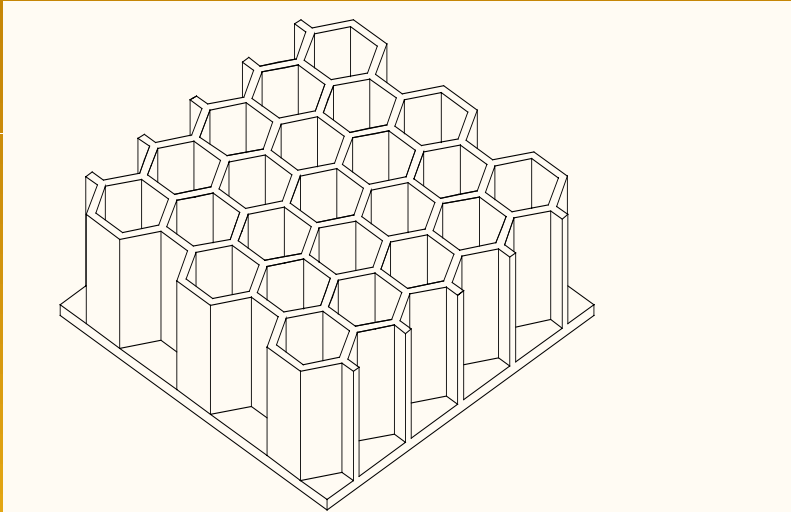


Micro Thermal-Chemical Power



MTO

MEMS



Approved for Public Release - Distribution Unlimited

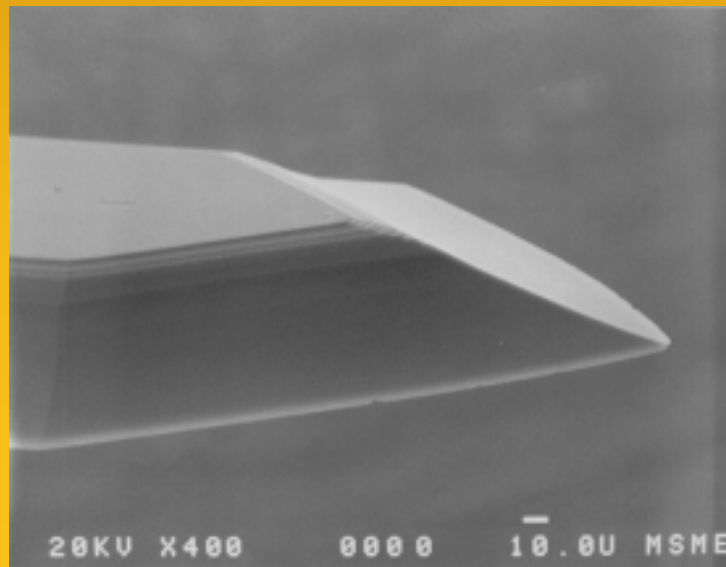
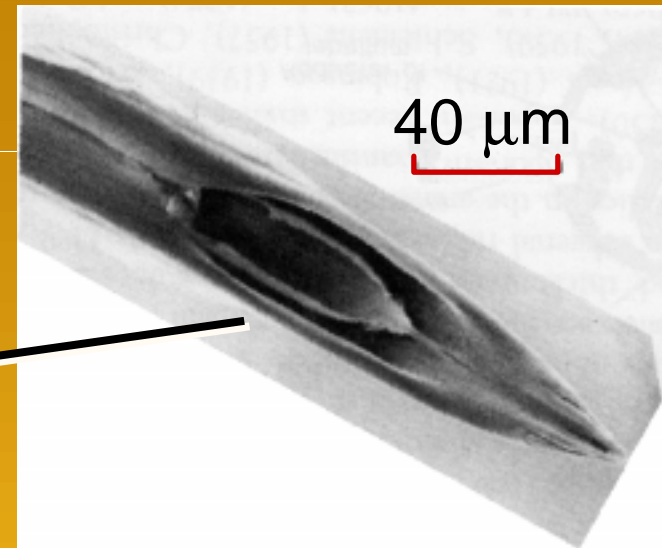
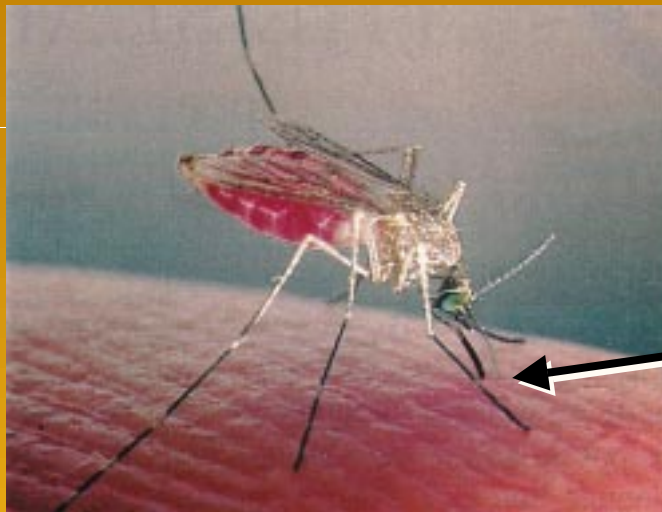


Micro Thermal-Chemical Power

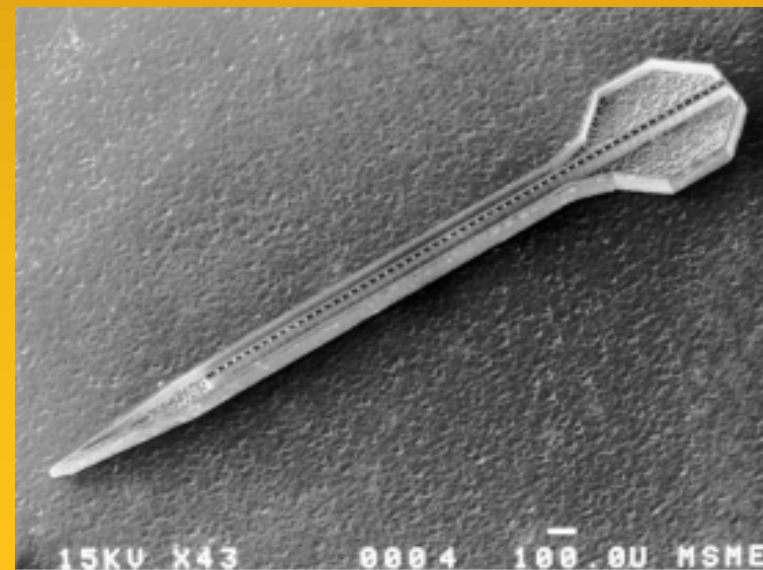


MTO

MEMS



Lancet width = 170 μm



Needle width = 150 μm

Approved for Public Release - Distribution Unlimited



Micro Thermal-Chemical Power



MTO

MEMS

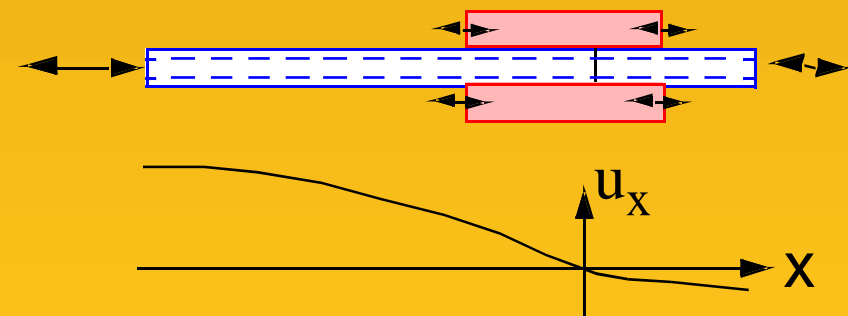
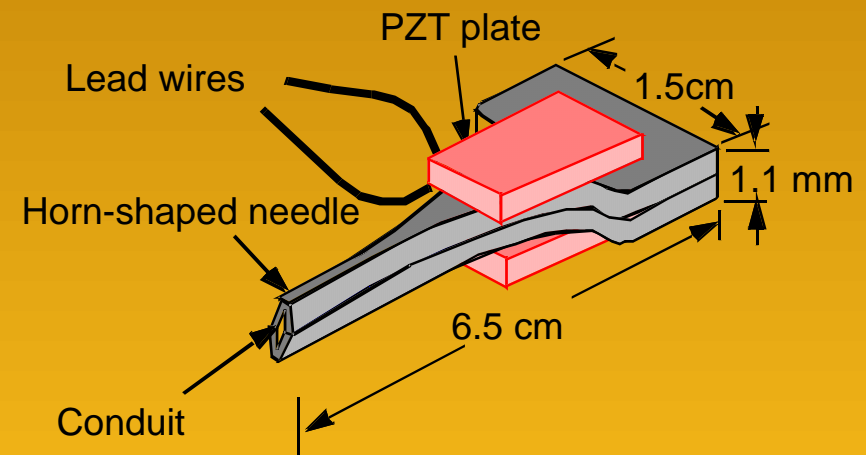


Water Droplets 20-35 μm at 72kHz



Ultrasonic Atomizer

(U of Wisconsin)



Axial Displacement Amplitude



Conclusions



MEMS is an enabling technology that will be part of both macro and micro systems.

- **Extreme miniaturization of low-power communication devices.**
- **Networks of sensors and actuators on macro devices for robustness and performance.**
- **Integrated systems for airborne sensing/communication.**
- **Thermal-chemical power on the microscale, for the microscale.**